

## CENTENNIAL SUPPLEMENT

—TO—

## ALBUM OF CLARKE, REEVES &amp; CO.

## PHOTOGRAPHS.

NO.

- 1, 2 and 3. Bridge over Hudson River at Albany.
- 4 and 5. Girard Avenue Bridge, Philadelphia.
6. Waterville, Maine.
7. Ticonic, “
8. Biddeford, “
9. Miramachi, New Brunswick.
10. Deep Gorge Viaduct.
11. Brunswick, Maine.

## PLANS.

- |                             |                |
|-----------------------------|----------------|
| 12. Albany Bridge,          | 70 feet spans. |
| 13. “ “                     | 177 “ “        |
| 14. “ “                     | Pivot draw.    |
| 15. Havre de Grace,         | 307 feet span. |
| 16. Miramachi,              | 200 “ “        |
| 17. Girard Avenue,          | 200 “ “        |
| 18. Montreal and Ottawa,    | 200 “ “        |
| 19. “ “                     | 150 “ “        |
| 20. New Orleans and Mobile, | 104 “ “        |
| 21. Lewiston, Niagara,      | 600 “ “        |
| 22. Rapallo Viaduct,        |                |
| 23. Thamesville, Canada,    | 185 “ “        |

## MODELS.

24. Pivot draw bridge. Locking apparatus.
25. Part of a 200 feet span.
26. Model of a viaduct.
27. Connections of viaduct.

## SPECIMENS OF IRON.

28. Phoenix columns.
29. Die forged eye bars.
30. Bar iron, bent and broken.
31. Pieces cut out of Phoenix column.

We submit the above photographs, plans, models and iron specimens, as illustrating the American style of iron bridge building, and in particular that system adopted at the Phoenixville (Pa.) Bridge Works, which uses Phoenix columns for the compressive members, eye

bars, die forged by hydraulic pressure, for the tension members, and rolled or riveted beams for those members subject to transverse strains. These parts are united by short castings, pins, screws and nuts, as is plainly shown in the models.

The accuracy of workmanship is such, that when a bridge is erected and loaded for the first time, and the load then removed, it will return to the calculated camber, which is usually taken at 1-1200 of the span.

Although we do not refuse to construct riveted lattice bridges, yet for all spans over 100 feet, we prefer the above described style of bridge, for the following reasons:

1. It has greater strength with equal weight, or equal strength with less weight of iron. For the proof of this we refer to the table of bridges following.

2. It necessarily requires better quality of iron, and better workmanship than the riveted lattice; at no greater, and in long spans, at much less cost. The method of manufacture itself guarantees a better quality of iron, and from all fitting being done by machine tools, better workmanship. This accuracy is always tested before each span leaves the works, by putting one truss together there. As all engineers know, very few riveted lattice bridges will come together without “drifting” the holes, and there is always a deflection after the staging is removed, from the dead weight of the bridge itself.

3. There is less exposure of surface to wind and weather, and hence greater durability. It has sometimes been stated as an objection to the Phoenix column, that a brush cannot be introduced to paint the inside after erection. This is true; but it is also true that the interior of these tubes can be painted by the same process by which the tubes of the Saint Louis bridge were painted after erection, viz: by filling each with liquid paint, and letting it run out into a vessel, and using the residue over again. This was proved to take more paint, but less labor than the usual mode of painting by brush. It is only necessary to leave the lower part of these tubes open, so that any water that gets in can

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run out, and the paint on the inside will last much longer than the paint on the outside, which is exposed to sun, rain and sudden changes of temperature. As a proof of this, we refer to the specimen pieces (No. 31) cut from Phoenix columns, and showing that the paint has not deteriorated after twelve years.

4. The pieces being small, and the total weight less than of riveted bridges, the cost of transportation is much less.

5. The necessary time required to erect a pin connected bridge of 200 feet span, after the false works or staging are put in up to the level of bottom chord, does not exceed two to three days. A riveted lattice of the same span would take as many weeks. As our rivers are subject to heavy freshets, the risk of loss would be much increased. After the bridge is erected, the ends of the screw bars of the lateral brace rods, floor hangers and counter tie rods, can be cold riveted over

the heads of the nuts, and thus make the bridge as immovable as if rivets, headed while hot, were used in connecting the parts.

6. We believe that owing to the concentration of material along the lines of strain, and hence the greater massiveness of parts, that our bridges will resist the shocks caused by collisions or derailment of trains, as well as bridges with riveted connections. Experience seems to confirm this view, as some of our bridges have been exposed to severe shocks of this kind, and in no instance have suffered any material injury.

To illustrate how much less iron is required to meet the necessary loads and strains by the American system, than by the riveted lattice system as practiced in England and on the continent of Europe, we give a table of the weights of some of our bridges as constructed, together with the loads they are designed to carry, and the strains upon the iron.





# TABLE OF IRON BRIDGES.

Selected from those actually constructed by Clarke, Reeves & Co. These bridges all have cross floor beams of iron. The longitudinal track stringers are of wood, unless otherwise mentioned. The general loads assumed for calculations, are the weight of iron in column 12, and weight of track assumed at 400 lbs. per lin. ft. Iron in tension strained 10,000 lbs. per square inch, except in floor beam hangers, where it is strained 7,500 lbs. In compression, Phoenix columns, upper chords of 12 to 15 diameters, from 8 to 10,000 lbs per square in., 20 to 40 diameters, 4 to 6,000 lbs. per square in. These bridges are designed with leveling end posts, unless otherwise described, and all with two trusses.

In what year built	WHERE AND FOR WHOM.	Deck or Through.	No. of Tracks.	Clear length of Span.	Width between centres of Trusses.	Angle of Skew, if any.	Panel Arrangement.			Single or double Intersec.	Rolling load, lbs. per lin. ft.		Weight of Iron per ft. of clear span.	Refers to		REMARKS.
							No.	Length.	Height.		General.	Panel and Floor System.		Album Letters.	Exhibition numbers.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
1875	Ottawa River; Montreal & Ottawa R'y.	D	1	50	10		5	11'	17'	1	4000	4000	594	C		Upright end posts.
1875	San Paulo & Rio Janeiro, Brazil.....	T	1	65½	15		7	9' 10"	10	1	3000	4500	605	E		Iron track stringers and sidewalks.
1872	Hudson River, Albany; N. Y. Central.	T	2	70	29	55°	7	10'	8	1	6000	6000	1420	F	2 & 12	Upright end posts.
1870	Baileysville; Boston & N. Y. Air Line....	D	1	79	10		8	10½	10	1	4000	4000	784	D		
1872	Little Wabash; Ohio & Mississippi R'y....	T	1	92	16		8	12	24	2	3000	3600	672	F		
1872	Greenbrier; Chesapeake & Ohio R'y.....	D	1	100	10		8	13	13	1	2500	3600	637	D		Upright end posts.
1875	New Orleans & Mobile R'y.....	T	1	104	15		8	13 ½	24	2	2500	4000	622	F	20	
1875	Ticonic; Maine Central.....	T	1	111	16		8	14 ½	28 9	2	2500	4000	655	F	7	
1872	Greenbrier; Chesapeake & Ohio.....	D	1	120	10		9	13 7	16	1	2500	3500	714	D		Upright end posts.
1874	Lennoxville; Grand Trunk R'y.....	T	1	118	16	61°	9	12 7	26	2	2500	4000	740	F		Upright end posts.
1874	Biddeford; Eastern, of Massachusetts....	T	1	130	16		10	13 3	26 ½	2	2500	4000	726	F	8	
1873	Little Androscoggin; Grand Trunk.....	D	1	135	11	85°	11	12 7	22	2	2500	4000	770	D		Iron track stringers.
1875	Norwich Falls; Norwich & Worcester....	T	1	145	16		11	13 2 ½	26 ½	2	3000	4000	910	F		
1870	Chester Creek; P. W. & B. ....	T	2	150	26		11	14	28	2	2500	3500	1320	F	19	
1875	Ottawa River; Montreal & O.....	T	1	154	12		11	14 ½	22	2	2500	4000	836	F		Upright end posts, ½ deck.
1869	La Salle; Illinois Central.....	D	1	160	16		12	13 8	28	2	2500	4000	954	F		
1875	Lewiston; Maine Central.....	½ D	1	161	16		12	14 10	28	2	2500	3600	810	F		
1872	Medora; Ohio & Mississippi.....	T	1	170	16		12	14 ½	28	2	2500	4000	856	F	7	
1874	Ticonic; Maine Central.....	T	1	172	16		12	14 8	28	2	2500	3600	873	F		Iron track stringers.
1875	Thamesville; G. W. of Canada.....	T	2	180	29		10	18 ½	34	2	4500	8000	1940	F	23	
1872	Hudson River, Albany; N. Y. C.....	T	2	177	28	45°	15	12 1	24	2	6000	6000	2585	F	13 & 1	
1874	Ristigouche; Intercolonial of Canada....	T	1	200	18		14	14 7	28	2	2800	2800	1140	F	9 & 16	
1874	Miramachi; Intercolonial of Canada.....	T	1	200	18		14	14 7	28	2	2800	2800	1105	F	6	
1874	Waterville; Maine Central.....	T	1	200	16	53°	14	14 7	28	2	2500	4000	1076	F	18	
1875	Ottawa River; Montreal & O.....	T	1	250	16		17	15	30	2	2000	3500	1285	F		Iron track stringers.
1875	New River; Chesapeake & Ohio.....	T	1	251	16		14	18 2	35	2	2240	3500	1421	F	15	
1875	Susquehanna River; P. W. & B.....	T	1	307	16		17	18 2	35	2	2240	3500	1895	F		
1876	Susquehanna River; P. W. & B.....	T	1	307	16		17	18 2	35	2	2240	3500	1895	F		
1874	Niagara River at Lewiston.....	T D	1 Ry 1 H	600	30		31	20	90	4	4000	4000	6700	F	21	{ Designed only. Proportioned for 1 railway track, 1 highway and sidewalk. Iron track stringers { Iron strained 12,000 lbs. to the square inch.
1872	Rapallo Viaduct.....	D	2	1380	ft. 19	50	high				4000	4000	940	K	22	{ Proportioned for 2 tracks, carries but one at { present.





From the preceding table, it will be seen that while the factor of safety of these bridges is ample, compared with their loads (see Album, pp. 22 and 23,) the amount of iron required is less than that required by bridges with riveted connections, and that this economy of material increases very rapidly with the length of span.

For short spans of less than 100 feet, economy of weight is not desirable, and for this class of bridges, we do not consider that riveted lattice girders are objectionable, as the difficulties of connecting together the parts by riveting which increase with the length of span, do not show themselves in these short spans.

The best bridges will always be built by those who, in addition to the theoretical knowledge of construction possessed by them in common with other engineers, have also that experience which practice can alone give.

It has been well said\* "that bridges do not fail from mistakes in calculating the strain sheets, but from the effects of vibration, buckling and rapid wear of important parts; the use of shapes that weaken the materials; inequalities in the material itself; and from similar causes not stated in the books; which assume different aspects under every change of proportion and dimensions; and which can only be inferred by means of a long familiarity with the behavior of similar structures during various periods of service, and with the processes by which materials and members are made."

It is on this account that we call particular attention to the great number of bridges that we have constructed between 1869 and the present time. We examine these bridges at intervals of not over two years, and their behavior under traffic is reported to us. We know the

condition of all the parts, and if anything requires to be done, we either do it ourselves, or call the attention of the officers of the railway, or those in charge, so that they may do it.

We are thus enabled to improve our designs from year to year, although we have found nothing radically wrong which would impair the safety or durability of our bridges.

The amount of bridges built by Clarke, Reeves & Co., between 1869 and the present time, is as follows:

Number of spans,.....	462
“ of lineal feet of single track,.....	54,050
Number of tons of iron besides roofs and other iron work,.....	22,000

The above bridges have been constructed at Phoenixville in accordance with our own designs. There have been built at Phoenixville for other engineers, on their designs, during same time:

Number of spans,.....	285
“ of lineal feet,.....	25,220
“ of tons of iron,.....	0,000

And the total is,

Number of spans,.....	747
“ of lineal feet,.....	79,270
“ of tons of iron,.....	31,000

We call the attention of foreign engineers to the Girard Avenue Bridge, as a specimen of our bridge work, near at hand and easily inspected. We extract from "London Engineering," of November 19th, 1875, the following description:

\* Address of A. L. Holley, before Institute of Mining Engineers, at Washington, February 22d, 1876.





# GIRARD AVENUE BRIDGE.

GIRARD AVENUE BRIDGE, of which we gave a two page and other engravings in our last number, and which we further illustrate in our present issue, spans the Schuylkill river in the city of Philadelphia, at the main avenue of approach to Fairmount Park and the Exhibition buildings, and is one of the great public works that will interest visitors to the Centennial Exhibition.

It is remarkable as the first attempt in the United States to combine the American system of pin-jointed, openwork girders, distinguished for their lightness of appearance, with a solid roadway of stone, constructed in that massive and substantial manner which is customary in England and on the Continent. To this is added a higher degree of architectural ornament than is common even here.

Its dimensions and cost do not differ much from our recent first-class bridges over the Thames, as will be seen from the following table:

NAMES.	Length.	Width.	Square Feet of Surface.	Cost.	Cost per Square Foot.
				£	£
London.....	904 53½		47,364	542,150	11 0
Waterloo. ....	1380 41½		57,270	579,915	10 0
Southwark. ....	800 42½		34,000	384,000	11 0
Westminster.....	1160 85		98,600	393,090	4 0
Blackfriars.....	1272 76		96,672	320,000	3 6
Girard.....	1000 100		100,000	267,500	2 13

The height of the roadway above low water is 55 feet. The girders rest on three piers and two abutments, and form three centre spans of 197 feet each and two side spans of 137 feet each. The height of the lower chord above low water is 23 feet. The bridge has a camber of 18 inches in its total length.

*Foundations.*—The foundations of each pier were constructed, as follows: The debris was removed from the rock bed of the river 30 feet below low water, by the common American single-bucket steam dredging machine. A double-walled bottomless caisson, 34 feet wide by 156 feet long, having the ends pointed, and formed of foot-square timbers well bolted together in the usual American manner of forming 'cribwork,' was sunk upon the bare rock, its bottom timbers having been carefully scribed to fit the inequalities of the surface. The spaces between the double walls were then filled with loose stone. The top of this cribwork came to within 16 feet of the surface of low water. The sides were then carried up by means of upright timbers placed 6 feet apart, and planked with 2 inch plank. This formed a cofferdam, not strong enough to be pumped out, but capable of excluding the current of the river, even during

freshets, and of forming a pool of still water through which the concrete could be lowered without its current being washed out. This dam was carried 20 feet above low water, or above the level of the highest floods. All this work above the crib was temporary, and removed after the construction of the pier. The internal space of the crib was then cleared by divers, using a centrifugal pump, which sucked the rock clean.

This interior space, 22 feet wide by 137 feet long by 16 feet high, was then filled with beton made as follows: Furnace slag was broken up by a Blake crusher, so as to pass 2 inch meshes. By placing this in a measured barrel of water the proportion of voids to solids was found to be exactly as 1 to 2.

A mortar was then made of one part of Pennsylvania hydraulic cement from the Coplay Works, and one part of clean sharp sand, the mixture standing thus:

Voids filled.....1 = { 1 part Coplay cement.  
1 part sand.  
Solids.....2 = { 4 parts crushed furnace slag.

This beton was mixed by hand on platforms, until each stone was thoroughly coated with mortar. It was then lowered in a box so constructed as to quite protect it against wash during descent, and easily discharge it after touching bottom. It was laid in 12 inches deep courses, carefully levelled by divers. This beton bore by test 308 pounds per square inch on cubes 3 inches square, after 30 days' immersion. The extreme pressure from bridge and maximum load is 45 pounds per square inch, or less than 3 tons per square foot. No sign of settlement or cracking has shown itself in any part of the structure.

The foundations of the abutments were made in a similar manner, except that a cofferdam of 12 inches by 12 inches sheet piles took the place of the cribwork caissons, and the earth was removed by a clam-shell dredge of the pattern so successfully used by Mr. C. S. Gzowski, at the International Bridge over Niagara river.

The masonry of the piers and abutments is rock-faced ashlar of Maine granite laid in mortar of one part Coplay cement to two parts of sand. The courses are from 20 inches to 30 inches high, stretchers from 5 feet to 7 feet long, with as much bed as rise. There is one header to every two stretchers reaching into the pier more than half its width. The courses bond on each other not less than their depth. The backing to this face-work is of concrete, made as heretofore described. The copings and parapets are of finely cut granite, but no other cutting has been done, except the necessary drafts, the object being to preserve the massive effect of rock-faced granite work.





*Superstructure.*—There are seven lines of trusses or girders placed side by side 16 feet apart, and united by horizontal and vertical bracing.

These trusses are of the well-known Phœnixville pattern of quadrangular girder. The upper compressive members and the vertical posts are Phœnix flanged columns, united by cast-iron joint boxes. The lower chords and diagonals are Phœnix weldless eye-bars, die forged by hydraulic pressure. Upon the tops of the posts, 12 feet apart, are laid heavy 51 inch Phœnix rolled beams, and upon these longitudinally 9 inch beams placed 2 feet 8 inches apart. These are covered transversely with rolled corrugated plates  $\frac{1}{4}$  inch thick, corrugated  $1\frac{1}{4}$  inches high by 5 inches wide. These form an unbroken iron platform upon which the asphalt concrete is placed.

The dead load of the structure with a moving load of 100 lbs. per square foot makes a total load of 30,000 lbs. per lineal foot, carried by seven trusses.

The limit of strain is 10,000 lbs. per square inch, reduced to 6000 lbs. per square inch as the compressive limit on posts. All points of contact are either planed or turned. The pins are of cold rolled iron, and the limit of error between pin and hole is one sixty-fourth of an inch.

The iron used in this bridge is double refined, or of "Phœnix best best" brand, capable of bearing the regular test of that quality of iron as follows: Ultimate strength, 55,000 lbs. to 60,000 lbs. per square inch; no permanent set under 27,000 lbs. to 30,000 lbs. per square inch; average reduction of area at point of fracture 25 per cent. The elongation of a 12 in. bar is 15 per cent.; and the cold bent of a  $1\frac{1}{2}$  in. round bar before cracking, 180 degrees, or hammered flat.

*Roadway.*—The corrugated iron plates which cover the bridge are themselves covered by 4 inch to 5 inch of asphalt, making a water-tight surface. The 100 feet of width is divided into  $67\frac{1}{2}$  feet of carriage way, and two  $16\frac{1}{4}$  feet sidewalks. The roadway is paved with granite blocks in the usual manner, except that it is divided into seven ways by two lines of iron trackways next the sidewalks for horse cars, and five lines of carriage tramways, made of cut granite blocks, 1 foot wide, laid to a 5 feet gauge. The gutters and curbstones are of fine cut granite. The sidewalks are covered for 10 feet of their width, with black Lehigh county slate tiles, 2 ft. square, laid diagonally.

On each side of the slate tiles are spaces 2 feet wide, which were originally laid with encaustic tiles. After one winter's frost these tiles became so much shattered that they were removed, and white marble tiles substituted in their place. The curbstone, 18 inches wide, makes up the remainder of the  $16\frac{1}{2}$  feet.

The sidewalks are separated from the roadway by rail-

ings of galvanized iron tubes with bronze ornaments, and are supported by cast-iron standards at every 6 feet. Every eighth standard is prolonged into a lamp post. There are eight refuge bays, each of which contains a cluster of six lamps, the supporting shaft rising through an octagonal seat, which forms its base. The outer balustrade and cornice is of cast iron with bronze open-work panels, and treated in a highly ornamental manner.

The bronze panels represent various birds and foliage, such as the phœnix, swan, heron, owl, eagle, tobacco, ivy, Virginia creeper, ferns and hops. These panels are of statuary bronze, cast under a pressure of 60 lbs. per square inch, which forces the metal into all the finest lines, and makes an extremely sharp casting; so sharp, indeed, that a casting made by this process from an electrotpe, has been used to print engravings from. There are between eight and nine hundred of these bronzes set in the balustrade, like pictures in a frame.

It is intended, at some future day, to place sidewalks inside the bridge, at the level of the lower chord. Access to these will be gained through the arched openings in the abutments, and this spot has been selected as a proper place for a drinking fountain. The bridge is painted salmon color, relieved by blue and gold; the cornice and balustrade are green and gold.

This bridge, notwithstanding its thorough construction and its large dimensions, was built in a remarkably short space of time as compared with works of similar magnitude. As the new bridge occupied the exact site of the old one, it was necessary, first, to build a temporary bridge 1050 feet long and 50 feet high above water, divided into spans of 100 feet each, resting on wooden cribs filled with stone. This was done in six weeks.

The construction of the permanent new bridge began May 11, 1873, and July 4, 1874, it was formally opened for public travel, and has remained in use ever since.

This rapidity of construction is due, first, to the mode adopted of laying the foundation under water, instead of pumping out that water; second, to the forethought displayed in making the temporary works strong enough to pass uninjured through a freshet which increased the depth of water from 30 feet to 46 feet; third, to the peculiar construction of the girders (which contain over 3500 tons of iron), which were made at Phœnixville from the ore, entirely by machinery, and without any hand labor; and, lastly, to the rapidity and facility of erection allowed by the pin-connected mode of construction.

The general dimensions of this bridge were fixed by Mr. Samuel L. Smedley, City Engineer of Philadelphia; while the design and construction are by Messrs. Clarke, Reeves & Co., of the Phœnixville Bridge Works, whose iron bridges and viaducts are known in all parts of the world.



